Training Induced Plasticity in Neural Function

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Sport Performance

• A result of muscle force and timing being coordinated by the central nervous system.

• From a neural perspective, muscle coordination is produced by both the recruitment of motoneurons as well as the increase in firing rates of those neurons.

• Muscle coordination also relies on the proper interpretation of sensory information.
The Motor Pool and Motor Output
Henneman’s Size Principle

Henneman’s size principle

* ordered recruitment of motor units
* small slow units active during low force contractions = smooth control
* large fast units active during high force contractions = poor control

Number of recruited units

tension
Recruitment and Frequency of Firing

Diagram showing the process from an electrode recording EMG, through software decomposition, to individual motor unit action potentials (MUAPs).
Leads to the Question

• With this limited array of options to produce movement, how does the central nervous system coordinate the many different types of sport behavior?
General Categories of Sport Performance

• Throwing and Kicking – Ballistic Type Movements

• Precision and Balance – Fine Control Movements

• Strength and Power – Maximal or near maximal movements
Neural Circuits We Can Examine in Humans

- Reciprocal Inhibition
- Presynaptic Inhibition
- Recurrent Inhibition
Neural Circuits that Influence Output
Reciprocal Inhibition
Reciprocal Inhibition

- Research shows distinctly different agonist/antagonist timing patterns in athletes trained for ballistic type movements, for example trained dancers and throwers.

- These patterns change with training, and are governed by the spinal pathway of reciprocal inhibition.
Regulation of Sensory Inflow

• Presynaptic control of motoneuron excitability has been implicated in a number of studies, from learning new skills to the high level performance of accuracy based sport skills.

• Presynaptic inhibition allows for greater or lesser influence of feedback from the muscle to alter the excitability of motoneurons.
What is the Role of Sensory Feedback?
Presynaptic Inhibition

• Regulates the flow of sensory information to the motor pool

• Fatigue produces a decrease in presynaptic inhibition

• Presynaptic inhibition is a neural adaptation to offset muscle fatigue in endurance trained athletes
What is the Role of Firing Rates?
## Motor Unit Firing Rates

<table>
<thead>
<tr>
<th>Muscle</th>
<th>Recruitment</th>
<th>Decruitment</th>
<th>Peak-40%</th>
<th>Peak-80%</th>
</tr>
</thead>
<tbody>
<tr>
<td>FDI (Low Force)</td>
<td>8.9±2.2</td>
<td>7.3±2.2</td>
<td>25.3±8.2</td>
<td>41.4±9.6</td>
</tr>
<tr>
<td>Deltoid (High Force)</td>
<td>12.9±2.5</td>
<td>9.1±2.5</td>
<td>26.3±4.8</td>
<td>29.4±3.4</td>
</tr>
</tbody>
</table>

Values represent pps
Recurrent Inhibition

• Although recurrent inhibition has been shown to change with fatigue in controls . . . .

• No changes in this circuit seems to be observed in highly trained endurance athletes

• Seems to be receptive to training regimens
Neural Control of Movement

• A Few Practical Applications
Rate of Force Development

Fig. 1. VM filtered EMG (A) and knee extensor force (B) signals recorded during an explosive isometric contraction. Both signals were analyzed in three consecutive 50-ms time windows from their respective onsets (0–50, 50–100, and 100–150 ms). EMD was defined as the time difference between the onset of each signal.
Rate of Force Development in Athletes

![Graph](image)

**Fig. 4.** Absolute (A) and normalized (B) RFD of explosive power athletes (dark bars; n = 9) and controls (light bars; n = 10) during explosive isometric contractions of the knee extensors. Data are mean ± SD. *P < 0.05, **P < 0.01, ***P < 0.001.
• What can occur in the initial 50 milliseconds for athletes to produce significantly greater rates of force development?

• Seems logical to conclude that this rapid force production is mediated by the neural system.
Elite (A) and Untrained (C) Archers

From Ertan et. al., 2005

How is it that trained archers can reduce the variability in muscle activation during the task?

Are highly skilled muscle release patterns caused by relaxation of the muscle and not activation of the muscle?

Can overtraining be identified via neural examination?
A Very Overlooked Neural Mechanism

• Role of sensory input to the motor pool

  – We often concern ourselves with the role of the central nervous system in activating the motor pool, but ignore the role of afferent information entering the system

Swimmers and shaving down?
• To date, the mechanisms involved in shaving has not been adequately defined; has been attributed to physiological, psychological and neural mechanisms, without a definitive answer.

• Perhaps the sensory input is altered, thus altering the excitability of motoneurons.
Cortical Drive

- Antagonist
- Synergist
- Intrinsic Properties

Motoneuron

Muscle Fiber

- Striations
- Nucleus
- Filaments containing actin and myosin

Sensory Regulation

Movement
Conclusions

• Sport Performance is produced, in part, by the central nervous system coordinating central neural commands which activate the appropriate motoneurons.

• It appears that three important spinal networks that regulate motoneuron excitability are reciprocal inhibition, presynaptic inhibition and recurrent inhibition.
Conclusions

• Each of these spinal pathways can be reliably measured in the athlete, and appear to demonstrate plasticity with training and fatigue.

• Future studies should examine the role of specific training programs on these pathways.

• The role of sensory feedback from the muscle is also a very under-represented area of study and may in fact regulate more of sport performance than originally hypothesized.
Thank You

Thank you for your invitation to present at this congress and special thanks to Dr. Caner Acikada, for this invitation.